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An Experimental Investigation of the Surface Pressure on Flat Plates in Turbulent Boundary Layers

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Abstract : The turbulence within the atmospheric boundary layer induces highly unsteady aerodynamic loads on structures. These loads, if not accounted for in the design process, will lead to structural failure and are therefore important for the design of the structures. For an accurate prediction of wind loads, understanding the correlation between atmospheric turbulence and the aerodynamic loads is necessary. The aim of this study is to investigate the effect of turbulence within the atmospheric boundary layer on the surface pressure on a flat plate over a wide range of turbulence intensities and integral length scales. The flat plate is chosen as a fundamental geometry which represents structures such as solar panels and billboards. Experiments were conducted at the University of Adelaide large-scale wind tunnel. Two wind tunnel boundary layers with different intensities and length scales of turbulence were generated using two sets of spires with different dimensions and a fetch of roughness elements. Average longitudinal turbulence intensities of 13% and 26% were achieved in each boundary layer, and the longitudinal integral length scale within the three boundary layers was between 0.4 m and 1.22 m. The pressure distributions on a square flat plate at different elevation angles between 30° and 90° were measured within the two boundary layers with different turbulence intensities and integral length scales. It was found that the peak pressure coefficient on the flat plate increased with increasing turbulence intensity and integral length scale. For example, the peak pressure coefficient on a flat plate elevated at 90° increased from 1.2 to 3 with increasing turbulence intensity from 13% to 26%. Furthermore, both the mean and the peak pressure distribution on the flat plates varied with turbulence intensity and length scale. The results of this study can be used to provide a more accurate estimation of the unsteady wind loads on structures such as buildings and solar panels.

Keywords : atmospheric boundary layer, flat plate, pressure coefficient, turbulence
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